What is claimed is:

1. A reflectometry apparatus, comprising:

a light source adapted to generate light that illuminates at least a portion of a surface of an object, the light source having an elongated configuration and extending from one end to another end;

an actuator configured to move said light source with respect to the object along a trajectory during a time period so that light from said light source sweeps across the surface of the object during the time period;

an optical imaging system configured to receive light reflected from the surface of the object during the time period, and to generate therefrom image data representative of a plurality of N images of the surface of the object during the time period; and

a data processor configured to determine one or more surface reflectance parameters for one or more areas of interest across the surface of the object by processing the image data, the surface reflectance parameters including at least one specular reflectance parameter.

2. A reflectometry apparatus in accordance with claim 1, wherein said one or more surface reflectance parameters comprise spatially varying surface reflectance parameters.

3. A reflectometry apparatus in accordance with claim 1, wherein said one or more surface reflectance parameters comprise at least:

a diffuse reflectance parameter ρ_d representative of the proportion of light incident on the surface that is scattered substantially omni-directionally while being reflected;

a specular reflectance parameter ρ_s representative of the proportion of light incident on the surface that is reflected substantially in a mirror direction to the angle of incidence;

and

a specular roughness parameter α representative of th roughness of the surface.

4. A reflectometry apparatus in accordance with claim 1,

wherein each image comprises a plurality of pixels, each pixel having an associated pixel value that represents the image brightness of a corresponding surface unit area on the surface of the object; and

wherein each image, represented by the image data, is captured at one of a succession of time points t_i ($i = 1, \ldots, N$) within a time period.

5. A reflectometry apparatus in accordance with claim 4,

wherein said data processor is configured to measure a reflectance trace for each pixel; and

wherein the measured reflectance trace of a pixel is representative of the detected intensity of light at the surface unit area corresponding to the pixel, at each time point t_i ($i = 1, \ldots, N$).

6. A reflectometry apparatus in accordance with claim 5, wherein said data processor is configured to compute a table of synthesized reflectance traces; and

wherein each synthesized reflectance trace in the table is representative of the intensity recorded at each time point of light originating from a virtualized rendition of said light source and reflected from each surface unit area corresponding to each pixel, and

wherein each synthesized reflectance trace in the table is computed using one of a predetermined set of model surface reflectance parameters.

7. A reflectometry apparatus in accordance with claim 6,

wherein the predetermined set of model surface reflectance parameters are derived from a parameterized reflectance model.

8. A reflectometry apparatus in accordance with claim 7,

wherein the parameterized reflectance model comprises an anisotropic reflectance model.

9. A reflectometry apparatus in accordance with claim 7,

wherein the parameterized reflectance model comprises an isotropic reflectance model.

10. A reflectometry apparatus in accordance with claim 9, wherein the isotropic reflectance model comprises an isotropic Gaussian lobe model, and

wherein the distribution of light reflected by a surface point from a direction (θ_i ϕ_i) to a direction (θ_r ϕ_r) in accordance with the Gaussian lobe model is given by:

$$f_r(\theta_i,\phi_i;\theta_r,\phi_r)=\frac{\rho_d}{\pi}+\rho_s\cdot\frac{1}{\sqrt{\cos\theta_i\cos\theta_r}}\cdot\frac{\exp[-\tan^2\delta/\alpha^2]}{4\pi\alpha^2}$$

where δ is an angle between the surface normal $\hat{n}$ at the surface point and a half vector $\hat{h}$ between the direction (θ_i ϕ_i) and the direction (θ_r ϕ_r) at the surface point.

11. A reflectometry apparatus in accordance with claim 6, wherein said data processor is further configured to compare the table of synthesized reflectance traces to the measured reflectance trace, for each pixel, and to thereby select from the model parameters the parameters that best match the measured reflectance trace.

12. A reflectometry apparatus in accordance with claim 11, wherein said data processor is configured to select the parameters that best match the measured reflectance trace by finding the values of the reflectance parameters ρ_d, ρ_s, and α that satisfy the following relationship for each pixel:

$$I(t)=\rho_d D(t)+\rho_s S_\alpha(t),$$

where *I(t)* represents the total observed intensity of the reflected light;

$S_\alpha(t)$ represents the intensity of light that is reflected from one or more areas of the surface of the object that are characterized by a specular roughness α, at an angle of reflectance that is substantially equal to the angle of incidence;
and $D(t)$ represents the intensity of light incident on the surface of the object that is scattered substantially omni-directionally while being reflected.

13. A reflectometry apparatus in accordance with claim 1, further comprising a synchronizer configured to synchronize the motion of said light source with the generation of images by said optical imaging system.

14. A reflectometry apparatus in accordance with claim 1, further comprising a laser configured to project a plane of laser light onto at least a portion of the surface as said light source is moved along the trajectory during the time period, so that a surface height can be determined for one or more areas of interest on the surface by observing a laser stripe that appears in each of the plurality of images as a result of the projection of the laser light plane on the surface.

15. A reflectometry apparatus in accordance with claim 4,

wherein said actuator is configured to move the light source along a first trajectory during a first time period and along a second trajectory during a second time period so that light from said light source sweeps across the surface of the object during each period;

wherein said data processor is configured to determine a surface normal for each point on the surface of the object by computing a first pair and a second pair of reflectance trace tables, and to determine a perturbation of the surface normal with respect to mutually orthogonal x- and z-axes.

16. A reflectometry apparatus in accordance with claim 15, wherein the first pair of tables is computed by setting the surface normal rotated about the z-axis by equal and

opposite degrees $+\delta$ and $-\delta$, and th second pair of tables is computed by setting the surface normal rotated about the x-axis by equal and opposite degrees $+\delta$ and $-\delta$.

17. A reflectometry apparatus in accordance with claim 1, further comprising a translucency measurement system adapted to measure a translucency parameter for the one or more areas of interest on the surface of the object,

said translucency measurement system including a second light source configured to illuminate at least a portion of the surface of the object from behind the object with respect to said imaging system;

wherein said optical imaging system is further configured to detect light transmitted through the object with said second light source illuminated; and

wherein said data processor is further configured to compute a translucency parameter ρ_{trans} for one or more areas of interest on the surface of the object based on the intensity of said transmitted light at each pixel whose corresponding surface unit area is within the one or more areas of interest.

18. A reflectometry apparatus in accordance with claim 17, wherein said second light source and said light source are the same.

19. A reflectometry apparatus in accordance with claim 1,
wherein said light source comprises a linear light source having a substantially cylindrical configuration,
wherein said trajectory comprises a linear trajectory, and
wherein said actuator is configured to translationally move said light source.

20. A reflectometry apparatus in accordance with claim 19, wherein said light source comprises a neon tube, said actuator comprises a translation gantry, and said optical imaging system comprises a digital camera.

21. A reflectometry apparatus in accordance with claim 3, wherein each surface reflectance parameter includes a plurality of spectral sensitivity components representative of a plurality of color channels for each pix_l.

22. A reflectometry apparatus in accordance with claim 1, wherein the trajectory comprises a substantially curvilinear trajectory, and wherein said actuator is configured to rotate said light source.

23. A reflectometry apparatus in accordance with claim 1, wherein said light source has a substantially curvilinear configuration.

24. A reflectometry apparatus, comprising:

a light source adapted to generate light that illuminates at least a portion of a surface of an object, said light source having an elongated configuration and extending from one end to another end; wherein said light source and the object are adapted to be moved relative to each other during a time period so that light from said light source sweeps across the surface of the object during the time period;

an optical imaging system configured to receive light reflected from the surface of the object during the time period, and to generate therefrom image data representative of a plurality of N images of the surface of the object during the time period; and

a data processor configured to process the image data so as to determine one or more surface reflectance parameters for one or more areas of interest across the surface of the object, the surface reflectance parameter including at least one specular reflectance parameter.

25. A reflectometry apparatus in accordance with claim 24, wherein the light source is adapted to be moved manually by an operator during the time period.

26. A reflectometry apparatus in accordance with claim 24, further comprising:

an actuator configured to create a relative motion of said light source and the object along a trajectory during the time period so that light from said light source sweeps across and illuminates the surface of the object during the time period.

27. A reflectometry apparatus, comprising:

a light source adapted to generate light that illuminates at least a portion of a surface of an object, said light source having an elongated configuration and extending from one end to another end, said light source and the object being adapted to be moved relative to each other during a time period so that light from said light source sweeps across the surface of the object during the time period; and

an optical imaging system configured to receive light reflected from the surface of the object during the time period, and to generate from the received light image data representative of a plurality of N images of the surface of the object during the time period;

wherein the image data are adapted to be processed by a data processor that is configured to determine one or more surface reflectance parameters for one or more areas of interest within the surface of the object using the image data, the surface reflectance parameters including at least one specular reflectance parameter.

28. A computer-readable medium having stored therein computer-readable instructions for a processor, wherein the instructions, when read and implemented by the processor, cause the processor to:

input and store data representative of a plurality of N images of a surface of an object, wherein said data are generated by a camera configured to receive light reflected from the surface while an elongated light source is moved so that light from the light source sweeps across the surface of the object, wherein each image is captured at one of a succession of time points t_i ($i = 1, \ldots, N$) within the time period, and wherein each image comprises a plurality of pixels, each pixel having an associated pixel value that represents the image brightness of a corresponding surface unit area on the surface of the object;

measure a reflectance trace for each pixel, wherein the measured reflectance trace of a pixel is a function of the detected intensity, at each time point t_i (i = 1, . . . N), of light reflected from the surface unit area corresponding to the pixel;

compute a table of synthesized reflectance traces, wherein each synthesized reflectance trace in the table is representative of the intensity, at each time point, of light originating from a virtualized rendition of said light source and reflected from the surface unit area corresponding to the pixel, and wherein each synthesized reflectance trace is computed using one of a predetermined set of model surface reflectance parameters; and

compare for each pixel the measured reflectance trace to the table of synthesized reflectance traces so as to determine the surface reflectance parameters that best fit the measured reflectance trace.

29. A method of determining one or more surface reflectance parameters of an object, comprising:

moving an extended light source along a trajectory during a time period so that light from said light source sweeps across the surface of an object during the time period, said light source having an elongated configuration and extending from one end to another;

receiving, during the time period, light reflected from the surface and generating a plurality of N images from the received light, each image being generated at one of a succession of time points t_i (i = 1, . . . N) within the time period, each image comprising a plurality of pixels wherein each pixel has an associated pixel value that represents the image brightness of a corresponding surface unit area on the surface of the object;

measuring a reflectance trace for each pixel, wherein the reflectance trace is representative of the recorded intensities at each time point t_i (i = 1, . . . N) of light reflected from the surface unit area corresponding to said pixel;

computing a table of synthesized reflectance traces, wherein each reflectance trace in said table is computed using one of a predetermined set of model surface reflectance parameters; and

comparing for each pixel said measured reflectance trace to said table of synthesized reflectance traces so as to determine the surface reflectance parameters that best fit said measured reflectance trace.

30. A method in accordance with claim 29, wherein said surface reflectance parameters comprise at least:

a diffuse reflectance parameter ρ_d representative of the proportion of light incident on said surface that is scattered substantially omni-directionally while being reflected;

a specular reflectance parameter ρ_s representative of the proportion of light incident on the surface that is reflected substantially in a mirror direction with respect to the angle of incidence;

and

a specular roughness parameter α representative of the roughness of said surface.

31. A method in accordance with claim 29, further comprising:

projecting a plane of laser light onto at least a portion of said surface while said light source is moved along said trajectory and said plurality of images are generated during said time period; and

observing a laser stripe that appears in each of said plurality of images as a result of said projection of said plane of laser light to determine the surface height for each point on said surface.

32. A method in accordance with claim 29, further comprising:

illuminating at least a portion of the surface of the object from behind the object with respect to an optical imaging system configured to detect light transmitted through the object while illuminated from behind; and

computing a translucency parameter ρ_{trans} for one or more areas of interest on the surface of the object based on the intensity of the transmitted light at each pixel.

33. A reflectometry apparatus in accordance with claim 1,

wh rein said actuator is configured to move the light source along two or more trajectories during two or more corresponding time periods so that light from said light source sweeps across the surface of the object during each time period; and

wherein said optical imaging system is configured to receive light reflected from the surface of the object during each time period, and to generate therefrom image data representative of a plurality of images of the surface of the object.